Fall 12-2004

Neuropsychology and Personality

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UNIVERSITY HONORS PROGRAM

SENIOR PROJECT - APPROVAL

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PROJECT TITLE: Neuropsychology and Personality

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

Signed: [signature], Faculty Mentor

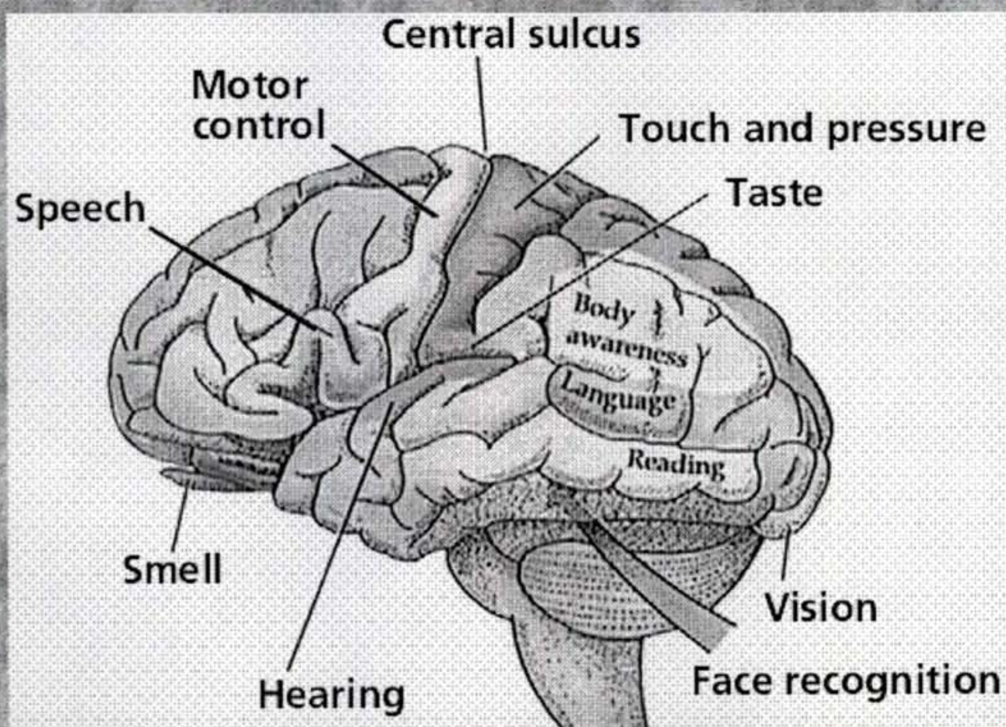
Date: 12/3/04

Comments (Optional):

I wish I could have seen the actual web pages, but the information seems well organized, presented at an appropriate level for the goals of the website, & could be quite useful. Few errors. More graphics would probably make it more user-friendly.

Neuropsychology and Personality

The main function of the brain is to organize and integrate information gathered by sensory organs into a herent representation of an organism's environment and to use this perception of the environment to generate propriate behavior. In other words, the brain coordinates the information it gets via the five senses and generates sponse. Since the brain governs the way an individual perceives the world as well as his or her actions, it is no rprise that personality can be greatly influenced by brain. The purpose of this website is to present information garding the regions of the brain that affect (or potentially) an individual's personality. I've tried to organize the aterial sequentially and simply, so that this page can be useful to high school biology students.



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Basic Cellular Biology

Before we move on to the more complicated and interesting stuff, there are some basic foundation facts that at are helpful to know about neurobiology and biology in general. With that in mind, here is a brief crash course i llular biology.

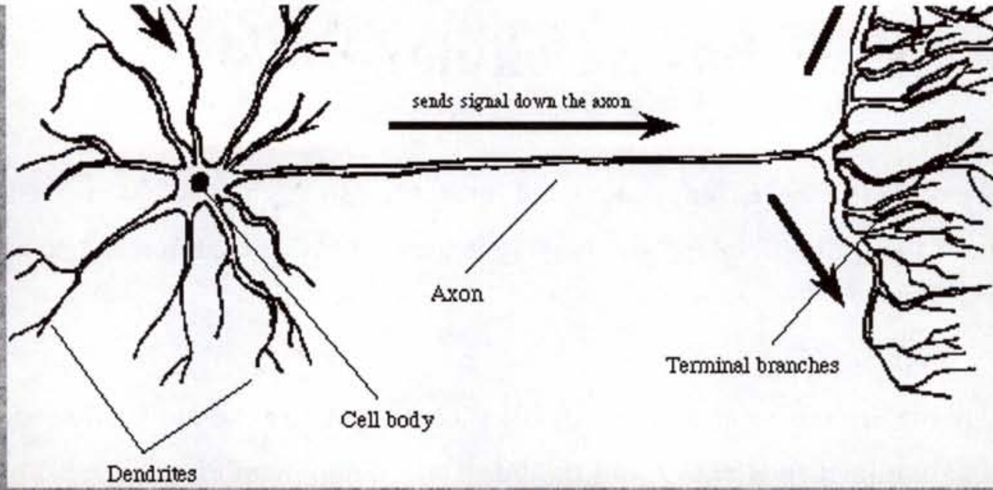
First of all, all living organisms (with the possible exception of viruses) are composed of cells. A cell is the bas ological unit (like an atom in chemistry). A cell can be a small component of an organism, or an entire organism o s own. Its outer wall is something like a sea of fatty acids in which various proteins are floating. Inside, there are ore proteins catalyzing chemical reactions (these are called enzymes), genetic material (the chemical blueprint for a rganism, called deoxyribonucleic acid, or DNA), and other molecules that the cell uses to maintain itself, such as igars (for energy) and structural proteins.

There are two types of cells: prokaryotes and eukaryotes. Prokaryotes do not have a cell nucleus, which is the orage site for genetic material (DNA) in eukaryotes. Eukaryotes also have smaller structures within them called rganelles. Organelles perform specific jobs within a cell that contribute to the cells survival, including energy roduction, protein manufacture and modification, breaking down contaminants, and storage of chemicals not irrently in use.

Prokaryotes are always single-cell organisms (like bacteria). All multi-cell organisms are composed of ikaryotic cells. Each cell in the human body has its own complete copy of that individual's DNA. However, even iough every cell has the same blueprint, not all of the cells are the same. This is because not all of the cells read the ime parts of the DNA strand. Therefore, cells are able to differentiate depending on what job they need to do and e able to work with other cells to help the organism survive.

There are many different cell types, but the two types most relevant to neuropsychology are neurons and glial lls. These are the two main cell types of the nervous system.

Neurons are messenger cells. The send and receive signals via small electric pulses transmitted down long llular processes called axons (send) and dendrites (receive). The place where the signal is handed from one neuron the next is called a synapse. The synapse can either be chemical or electrical. Most synapses are chemical, which eans that the signal is handed from the first neuron to the second by way of a chemical messenger, called a eurotransmitter. The neurotransmitter can either stimulate or inhibit another electrical pulse (another signal) in th ext neuron. In an electrical synapse, the two neurons are in direct contact with one another and the electric pulse om the first continues right on into the next.



Neurons receive signals from sensory cells, such as pressure receptors in the skin (touch sense), and send them higher processing centers where the information is analyzed and a response is generated. These higher processing nters include the brain and the spinal cord. Circuits of neurons then generate a response and still more neurons rry the response information to the appropriate destination (usually a muscle).

There are several types of glial cells, each with a different function. Some surround chemical synapses and gulate the amount of neurotransmitter that reaches the target cell. Some surround axons so that the signal travels ster. Still others play a maid role, and maintain the environment of the neurons.

The easiest way to think about all this is to compare your brain to a computer. There is some kind of input: a ystroke on your computer, or a signal from a taste receptor on your tongue for your brain. Then there is mputation. Both systems use a bunch of 0's and 1's (off/on signals). The only difference is that a computer uses ansistors, while your brain uses neurons. Then there is some kind of output. In your computer, the keystroke lead a program opening. In your brain, the signal from your taste buds is processed and your brain sends the signal to iew and swallow the bite of pizza you just took.

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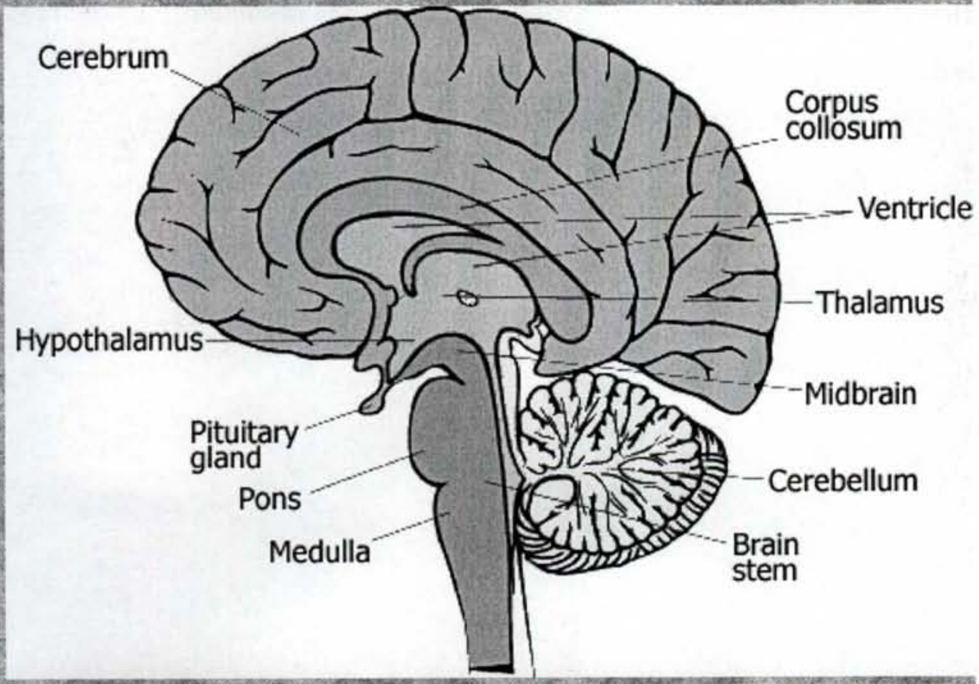
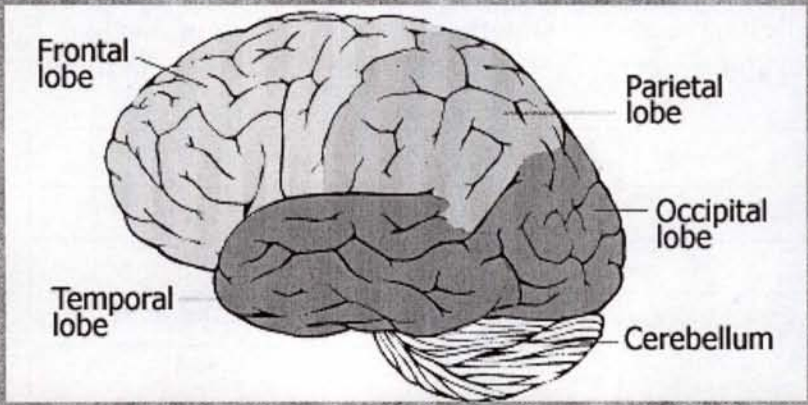
Brain Anatomy

The human brain is composed of two roughly equal halves (hemispheres), each divided into the several arts. Among these are the medulla, the cerebellum, the pons, the midbrain, the hypothalamus, the thalamus, the asal ganglia, the limbic system, and the cerebral cortex (1). The table below highlights their functions.

Brain Division	Major Function(s)
Medulla	Controls heart rate and respiration
Cerebellum	Motor control
Pons	Information flow out of the brain
Midbrain	Processes auditory and visual input
Hypothalamus	Motivates self-preservation behavior
Thalamus	Data organization
Basal Ganglia	Motor control
Limbic System	Emotional integration and memory
Cerebral Cortex	Deciphers sensory input, object recognition, and conscious thought



The cerebral cortex is further divided into four lobes: the Frontal, Temporal, Parietal, and Occipital bes. Each lobe performs several functions. The Frontal lobe contains the Olfactory Cortex, the Primary Motor ortex, and is involved in executive function, working memory, and various emotional functions. (We'll return to th st three items shortly.) The Temporal lobe contains the Primary Auditory Cortex and the Occipital lobe contains e Primary Visual Cortex. The Parietal lobe contains the Primary Somatosensory Cortex, which is where sensory put is integrated into a coherent picture of the environment. The orientation of the four lobes is shown in the figur low.



There are many functions localized to specific parts of the cerebral cortex, so there are a few positional terms ıat you need to be familiar with. The 'dorsal' side of your brain is the side toward the top of your head. The 'entral' side is the bottom of the brain, toward your neck. The 'anterior' is toward the front (your face), and the ıosterior' is near the bottom (toward the neck). 'Left' and 'right' refer to the two hemispheres of the brain, while ateral' and 'medial' denote a position away from and near to the middle, respectively. The notation is used as llows: the left dorsolateral frontal lobe indicates the portion of the frontal lobe that is hear the top and side of you ead on the left side.

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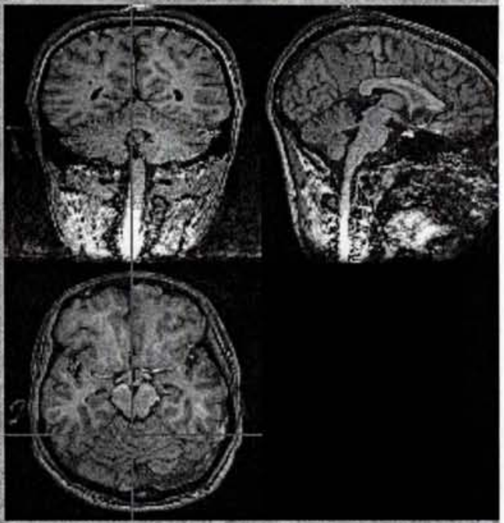
Neuroimaging

Another major method of study is brain imaging, or neuroimaging. This type of research includes a whole ınge of noninvasive maneuvers, such as functional magnetic resonance imaging (fMRI), electroencephalogram ːEG), positron-emission tomography (PET), and computed tomography (CT). All of these procedures are different ıkes on the same concept: measure brain activity and/or health without surgery (3). These tests are performed on ealthy and brain-damaged individuals in order to determine the activity (or inactivity) of various brain regions ıring specific activity. These experiments are highly valuable, because they have been able to accurately locate the rocessing centers for many important brain functions.

lagnetic Resonance Imaging (MRI)

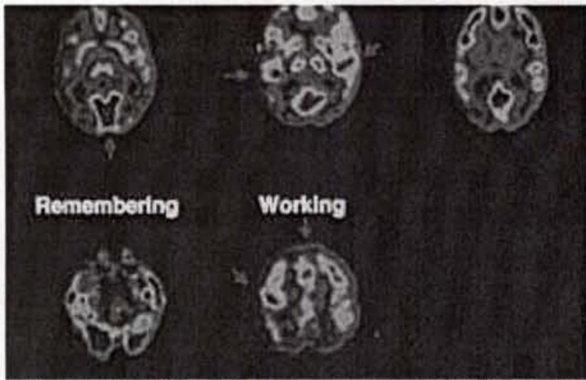


An MRI makes use of radio and magnetic waves to create a three dimensional image of soft tissue within the ody. The test subject's entire body is placed inside small chamber made of a large magnet. The magnet causes all ıe hydrogen atom protons within the body to spin in the same direction, so that when a radio wave is applied, they nit a small signal of their own (4). A receiver collects these data and converts them into an image based on their ılculated source. A functional MRI (fMRI) scan involves gathering several images of the brain in rapid succession ıd using the changes between these images to determine brain activity (7). Functional MRI scans are favored ecause they have a relatively high resolution both visually and temporally (1). That is, they show the brain in great etail, as well as being good at designating changes in activity over time.

lectroencephalogram (EEG)

An EEG uses electrodes attached to the scalp to measure electrical activity within the brain. Remember, the eurons in the brain fire off electric pulses when they are sending a signal, so measuring electrical activity really easures brain activity. This type of test is usually performed with some type of stimulus recognition experiment, ecause there are easily recognizable changes in electrical current within the brain when an individual identifies and ıalyzes a target object (5).

ositron-Emission Tomography (PET)



A PET scan utilizes a radioactive material injected into the test subject to measure the metabolism (or activity ' specific parts of the body (6). The procedure is fairly simple. The patient is injected with the radioactive material. hich is associated with a specific molecule that the investigator wishes to follow, such as glucose (the body's main iergy source), oxygen, or a neurotransmitter (1). The patient is then placed in a chamber much like an MRI iamber, except that there is a radiation sensitive material surrounding the subject rather than a magnet. When the ody uses the radioactive material, gamma radiation is emitted and detected by the chamber walls. This information used to generate a map of the body's usage of the targeted material (6).

'omputed Tomography (CT)

Computed tomography, also referred to as Computed Axial Tomography (a CAT scan), is simply a cross :ctional or three-dimensional composite of many x-ray images taken from many angles around the body. CT image in be used to find abnormal structures within the body, such as tumors and blood clots, or to study normal bone an rgan tissue (8).

The general formula for experimentation with neuroimaging is to ask the test subject to perform some type of sk or observe some stimulus that isolates the brain function the researcher wishes to study. While the test subject i erforming the task, brain activity is measured by one of the above four tests. The experiment is usually repeated veral times with each test subject using one or two different scanning methods. The experiment is also usually erformed with a variety of different test subjects, both normal and brain-damaged.

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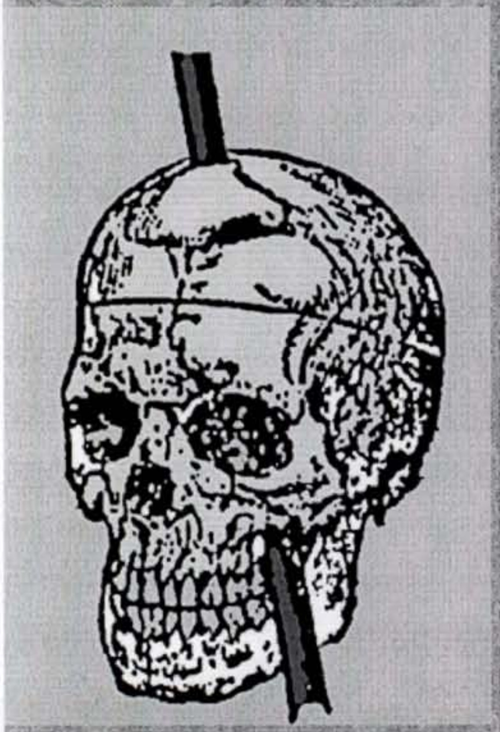
Phineas Gage

Phineas Gage was the first case of neuropsychological study, as well as the motivation for this website. In 184 age was working as a railway foreman when an accident with an iron tamping rod caused severe damage to his rain (probably his frontal lobe). Gage was leveling rock at a railroad construction site in Vermont, when he droppe s tamping rod (3'8" long, 1.25" diameter) into a well of uncovered blasting powder. The powder exploding on ntact and sent the iron rod rocketing through the bottom of Gage's jaw and out the top of his head (2). However, age did not die. Under the supervision of Dr. John Harlow, his wounds healed within a year, but his personality ha mpletely changed. Before the accident, Gage was even-tempered, hard working, and competent. Afterwards, he as described as being very childish. Dr. Harlow, in his famous analysis of the case, observed that Gage had become ort-tempered, impatient, easily distracted, rude, stubborn, and somewhat scatter-brained (2).



The case of Phineas Gage is characteristic of one of the major methods of neuropsychological research. That i interested investigator finds an individual with some sort of localized brain damage and studies any abnormal aracteristics. If there is some sort of deficiency, the representative function is attributed to the damaged portion of e brain.

However, there are several obstacles in this method of research. First is that brain damage is almost never calized to one specific region of the brain (3). This can cause all sorts of problems with an experiment. First and remost, it is difficult to tell which of the damaged regions accounts for the observed abnormal behavior. The only ay to narrow it down is to perform multiple tests on multiple subjects with damage to overlapping areas. Even the ay to narrow it down is to perform multiple tests on multiple subjects with damage to overlapping areas. Even the is very difficult to label a portion of the brain as having a specific function because there tend to be several areas o e brain that participate in one process. Furthermore, it is often difficult to gather a suitable group of test ıbjects. For instance, a thorough experiment would require a somewhat large group of subjects all with similar juries, which is difficult to do, as survivors of selective brain damage tend to be in short supply (3). Despite all thes ıadblocks, there have been many successful studies on patients with brain damage, especially with damage to the refrontal cortex (the region of the brain just behind the forehead).

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The Prefrontal Cortex

he prefrontal cortex (PFC) is located in the frontal lobe just behind the forehead, and has been shown to be active i :ecutive function, working memory, and some emotional processing (9,10). The following overview of these functio :rves the purpose of presenting the contribution of the PFC to the personality of an individual.

:xecutive Function

he simplest way to define executive function is the ability to plan an action (9). This process encompasses many eps. The first is to identify a goal or a need. Next, methods of achieving the goal are weighed as viable alternatives. /hen the best alternative is chosen, action is initiated. The tasks must often be performed in the proper order for th ›al to be achieved. Motivation becomes an issue, as the goal may not be immediately achieved. There may be also b ›stacles to progress, and problem-solving skills are employed to develop a new plan in order to continue on toward ie ultimate goal. Finally, executive function terminates action (11).

amage to the frontal lobe can negatively affect any number of these processes of executive function. However, due ie great number of connections the frontal lobe maintains within itself and with other parts of the brain, localizatio ' these specific functions is difficult to demonstrate (1). The following is a brief summary of the various malfunctio ' executive function.

amage to the portions of the frontal lobe governing initiation of action causes a condition called psychological inerti). Individuals with damage to this portion of the brain have trouble with identifying needs and thus with beginning ı activity. However, once they begin action, they have difficulty stopping. They are also easily influenced. For :ample, a researcher asked a patient with psychological inertia if he was thirsty. The patient responded that he was ›t. However, whenever the researcher suggested that the patient should take a drink if he was thirsty, the patient ould always take a drink (1). This type of case is not limited to verbal cues, either. Individuals with psychological ertia will also respond to cues in their environment, a condition called environmental dependency syndrome 2). For example, if the subject sees a keyboard, he or she will sit down and begin typing.

Damage to the action initiation system seems to separate conscious thought from action (13). In tests where ıbjects were asked to sort cards into piles based a certain characteristics, they incorrectly sorted the cards while ating that they knew that they were doing so. This has led some researches to the opinion that psychological inertia · a disconnection of thought and action within the frontal lobe, deprives these patients of their free will). Regardless of whether free will is involved in this problem, it is certain that a malfunction of action initiation has severely detrimental effect on one's intellectual independence. Other types of damage to the medial PFC have been ıown to decrease motivation in general (22). These results have implications regarding ambition and perfectionism).

second malfunction of executive function can occur at the planning stage. At this stage in the process, the brain ha :t a goal and begins to use the information available to devise a plan (cognitive estimation) (1). When damage to the :gions responsible for this function occurs, the individual is no longer capable of complex, or abstract, ıought. These subjects are competent to follow concrete plans, but they are unable to create their own when given a ›al (14). These individuals also tend to be deficient in estimation of mundane subjects, such as the price of applianc ıd groceries, or their own ability to plan and perform chores (15, 16). Finally, these patients have trouble estimatin ie potential behavior of other individuals (an ability called theory of mind), leading to a limited capacity for empath 7). On a somewhat larger scale, these deficiencies mean that these patients do not have the capacity to plan out hov achieve something like a life goal or a New Year's Resolution, and they have difficulty working with a group to nish a task, because division of labor is a foreign concept to them.

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amage to executive regions may also cause deficiencies in problem solving skills (18). This is caused by mental flexibility, or an inability to adopt an alternate point of view in dealing with the problem. This type of damage also fects the ability to adapt to new situations and to create new uses for an object (1). Habit rules the actions of dividuals with this type of malfunction, because creativity is impossible.

amage to the frontal lobe also has the potential to frustrate the ability to work toward a known goal (1). This cludes focus, organization of steps (or sequencing), and progress analysis. The dorsolateral portion of the PFC has een implicated with the task of maintaining focus (1). This region keeps maintains an 'attentional set' of relevant formation and actively works to exclude extraneous details (19). The ability to discern to proper of order of action take in order to best reach a goal can also be impaired by damage to the frontal lobe. This type of deficiency migh iuse an individual to mail out a blank set of college application forms before filling out another set, which might be ft at home. Finally, dysfunction in the frontal lobes can result in an inability to judge whether a task is actually elping to achieve a goal (1). The combination of these three deficiencies results in erratic behavior, similar to ADHI id the behavior of Phineas Gage (insert link) after his accident.

wo prominent theories concerning the mechanism of executive function are the supervisory attention system (SAS) ieory and the executive knowledge model (9). The SAS theory views executive function as being similar to a omputer program in the way it deals with a problem. It states that there are 'schemas,' or pre-programmed, itomated plans, on how to deal with the mundane situations that an individual might encounter (20). For example, ie electric bill-paying schema would involve finding the checkbook, writing a check for the amount of the bill, and ailing the bill to the electric company. Learned triggers (receipt of the bill in the above example) prompt the brain action in these scenarios. The supervisory attentional system (SAS) comes into play when a novel situation is icountered or a behavioral change is attempted (i.e. trying to break a habit). The SAS is responsible for analyzing ie problem, developing a plan, initiating action, and monitoring progress (20). The SAS also oversees the ppointment of schemas to ensure that the correct one is chosen for a given task (left dorsolateral PFC), searches the emory for the appropriate actions (right ventrolateral PFC), and monitors behavior (right dorsolateral PFC). his theory is particularly strong because it includes a model for the interaction between the nature and nurture ipects of an individual, because the events that trigger an action schema are learned, not programmed. In other ords, the SAS theory helps to reconcile the two major perspectives on how a personality is forged. Another way to xplain this concept is the transactional model of behavior. The transactional model states that an individual's atural qualities and his or her environment each has an effect on the other (3). That is, an individual can affect his er environment, which in return affects the individual, who learns and responds to the environment, and so on. Th arning of schema triggers is also a good way to imagine how habits are formed.

nother model that incorporates the influence of the environment into behavior patterns is the executive knowledge odel (9). This model states that managerial knowledge units (MKUs) are stored in the PFC. These MKUs are milar to the schemas in the SAS model. They are arranged in a hierarchy (ladder system) of simple to complex ehaviors. Simple MKUs become associated with another by learning and experience to generate responses to more omplex situations (1). The more often an MKU is called into use, the more automatic and ingrained that behavior ecomes. Thus, we have another mechanism for habit, as well as an explanation for the maintenance of mundane ipabilities even in individuals with damage to the frontal lobe.

he effects of executive function on the personality of an individual can most easily be demonstrated by reviewing th ise of Phineas Gage. Recall that after his accident, Gage was easily distracted, scatterbrained, and somewhat responsible. These are all symptoms of damage to the frontal lobe and executive function. Differences in these trai in also exist in normal individuals. While most people have the DNA necessary to build a brain, no two people have ie exact same DNA. That means that there will be minor differences between the brains of any two people. These ifferences will be analogous to the difference in height, weight, and hair color those two people might have. These ifferences in the blueprints that each brain is built with can cause minor differences in the some of the rocesses. Thus, one individual may be slightly better at dealing with new situations than another. Life experience in also cause differences between brains. Since learning is heavily involved in the development of schemas or MKU depending on which theory you prefer - experience is incorporated into the physical aspects of the brain (as emory). These experiences then resurface as behavior.

emory). These experiences then resurface as behavior.

Vorking Memory

Working memory, localized mainly in the dorsolateral PFC, is basically the attentional set of executive ınction. It holds a small amount of information relevant to the task at hand for a few seconds (1). Recent studies ıve shown that it also plays a role in anticipating events (21). This is a logical function, because as a holding point f nowledge of past events, it is ideally placed to relate possible future events based on observed patterns.

Deficits in working memory have a drastic effect on an individual's ability to interpret events. Since less formation is in storage about current events, it is more difficult to build relationships to the preceding events. The sult is that pattern recognition and planning ability are negatively impacted, and the individual becomes dependen n more recent stimuli to determine action (1).

Emotional Control

It has been frequently demonstrated that the ventral prefrontal cortex is intimately tied to the limbic system, hich is one of the primary systems responsible for emotional processing (9).

The ventral PFC controls positive conditioning (reward associations), as well as inhibition; damage to the teral ventral PFC has caused irritability and impulsive decision making (23). The same study also showed that entromedial PFC plays a role in risk assessment. Subjects with damage to the medial ventral PFC continually ımbled on high risk bets that had a greater immediate value, but had less value in the long run. Other research dicates that the ventromedial PFC responds rapidly to emotional stumuli and probably plays a first response role 5).

Several other studies have demonstrated a connection between the orbitofrontal PFC (the region along the ont bottom edge of the brain) and positive sensations from the taste, sight, and smell senses (1). Some of these xperiments have also found that people with damage to the OFC disconnect their consequences from their actions nd frequently behave inappropriately (24). These subjects tend to disregard the possible results of their actions in eir attempts to obtain the most immediate gratification. One study even linked the OFC to moral values (24). The FC also seems to be functional during the re-learning process. For example, in a test where the rules changed, ıbjects with damage to the OFC were unable to adapt (1).

It is reasonable to conclude that the dorsolateral PFC (DLPFC), with its role in working memory and focus, so has some role in emotional processes, since most people have experienced how emotion can affect the thought atterns (1). As stated above, the DLPFC is charged with the responsibility of integrating past experiences into ırrent activity. When emotional control is added to this responsibility this region becomes extremely important for lf-perception (9). The role of the DLPFC in executive function and emotional integration leads action based on notion in a positive response (approach) or negative response (withdrawal) pattern (26). The two response classes re localized to the two hemispheres: the approach to the left and withdrawal to the right.

The DLPFC isn't the only region of the PFC that displays a different function in each hemisphere. In fact, th hole PFC seems to be divided. Damage to the left PFC causes a 'catastrophic reaction' where subjects experience mething like a continuous emotional breakdown (the right side regulates negative feelings). On the right side, amage causes a 'euphoric indifference' reaction, where subjects are in a perpetually good mood despite their injuri he left side regulates positive feelings) (27). The two halves seem to contend with one another to form a balance of ood. The balance of activity can fall on different points of a mood continuum depending on the individual. In othe ords, this type of brain activity is a factor in whether an individual has an overall positive or negative attitude.

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The Parietal Lobe

Two of the major functions of the Parietal Lobe are integration and interpretation. The parietal lobe is the sit here information from sensory input converges and is molded into a representation of the surrounding ıvironment. The parietal lobe is also the region where emotional stimuli are interpreted (1).

One of the primary functions of the right parietal lobe, as far as emotional processing is concerned, is to terpret visual and auditory emotional content, such as facial expressions and tone of voice (1). The right parietal be is where the brain makes the jump from observing a frown and slanted eyebrows to noticing that the person it is eing is angry (28). This social skill is enormously important, as a great deal of communication is accomplished with ody language. Interpreting tone of voice, or prosody, and more importantly, integrating tone of voice with facial xpressions is another task of the right parietal lobe.

Patients with damage to the right hemisphere have serious problems assessing their social surroundings, but so have difficulty with assessing the rest of their environment. The parietal lobe's function in integrating other nsory input it the main cause of this deficiency. Research on story interpretation has suggested that skepticism is nother function of right parietal lobe, as subjects with damaged right hemispheres displayed poor comprehension nd judgment of plot (29).

The right parietal lobe is also responsible for emotional display. Prosody and facial expressions are both ontrolled by the right side (1). It is interesting to note, however, that the right side is not solely responsible for notional output. The left side moderates the emotional output of the right side. This relationship roughly orresponds to a conscious control of subconscious emotion (30). This phenomenon is actually visible in many facial xpressions. The left side of the face - controlled by the right hemisphere - tends to display more emotional content an the right side of the face, which is controlled by the left hemisphere (30).

The affects of the parietal lobe on personality are potentially very great. Since personality depends on erception of the individual's environment, it is also dependent on the ability of the parietal lobe to interpret and tegrate sensory input. Dominance changes between right and left hemispheres can also lead to an individual owing more or less emotion, respectively.

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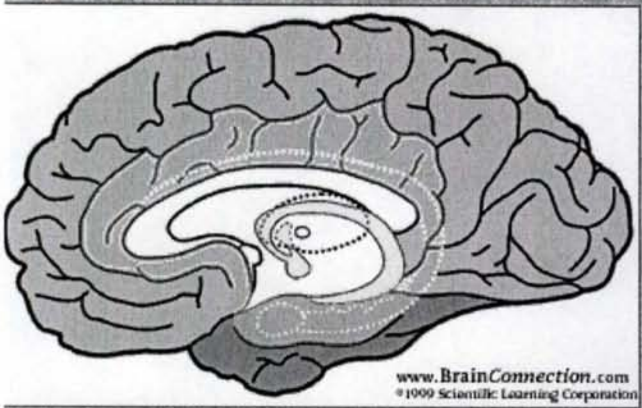
The Amygdala

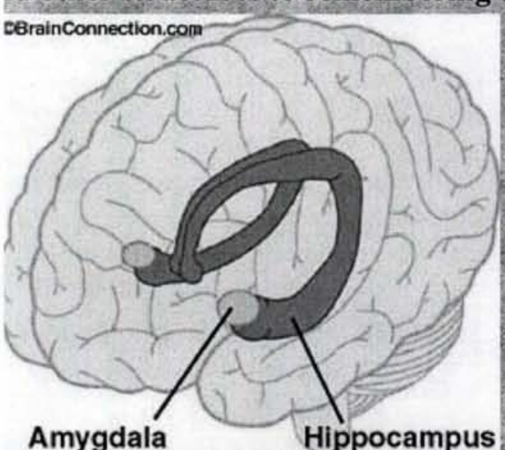


(The Limbic System)

The amygdala is a subcortical (below the cortex) brain structure. It is also a part of the limbic system, which as the first recognized center for emotional processing. Other structures of the limbic system include the ypothalamus, the thalamus, the hippocampus, and the cingulate cortex.

The amygdala has strong connections to negative feelings such as fear and suspicion (1). It is responsible for elping to identify alarming sounds, and also responds when an individual sees or hears something that he or she is fraid of (31,1). Two of the most important functions of the amygdala seem to be fear conditioning and emotional emory (32, 33). Fear conditioning is the subconscious association of neutral stimulus with a negative one. A simple xample is dog training. In order to train a dog not to jump on the couch, its owner shakes a can of coins at it every me the dog jumps up. Eventually, the dog begins to associate jumping up on the couch with the unpleasant noise, nd ceases its attempts to lie on the couch.

Fear conditioning depends on a link between the memory of the negative stimulus and the fear response it enerates. This is another function of the amygdala. Fear responses are in many cases a necessary element of the sel reservation instinct, so events causing fear must be faithfully recorded. The special attention given by the amygdala nd other structures to remembering threatening situations is called the memory enhancement effect (33).

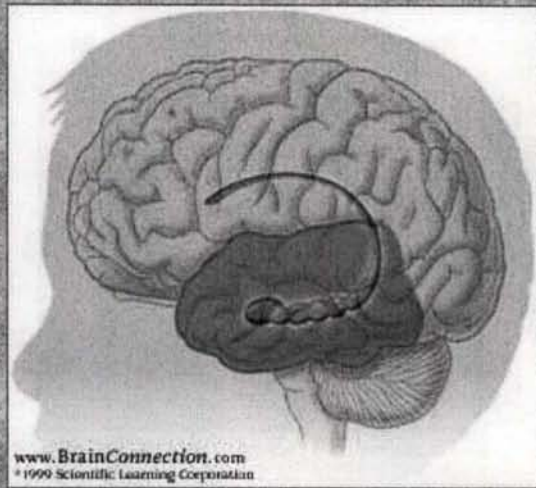


Fear responses often require quick action as well as clear thought. In order to accomplish both of these, there re two main routes that information can take to reach the amygdala (1). One route is directly into the amygdala om the thalamus (the brain's incoming information distribution center). This route allows the amygdala to perforr rough assessment of the situation and generate action quickly (34). The second route carries the signal through the eocortex, first, so that a more complete appraisal of the situation is possible.

Much of the work performed by the amygdala is subconscious, and this has sparked some interesting esearch. One line of study, called race evaluation, measures the unconscious attitudes of people toward other aces. Amygdala activity (fear response) is measured by fMRI while test subjects are shown faces or individuals elonging to different ethnic groups. This research has shown that consciously stated opinion and subconscious esponse do not necessarily agree with one another (35). This leads to some rather interesting ideas. Fear may be ermanently hardwired into the brain; it may be impossible to overcome. Biases obtained in early developmental

sponse do not necessarily agree with one another (33). This leads to some rather interesting ideas. Fear may be ermanently hardwired into the brain; it may be impossible to overcome. Biases obtained in early developmental ages may be irreversible, as well.

The Hippocampus



The hippocampus is largely responsible for organizing, storing, and retrieving long-term memory (1). This formation also includes emotional content; the hippocampus is the site where emotion is applied to specific situatio nd scenarios in memory. For example, running away from another competitor in a race is associated with a much fferent emotional sensation that running away from an angry bully. The ability to store this type of information in fect gives the hippocampus 'authority' over emotional context and appropriate emotional expression (26).

The Cingulate Cortex

The cingulated cortex, which wraps around the top middle part of the brain, has a variety of functions. One c em is general pain perception. Subjects who received surgical damage to their anterior cingulated cortex as a eatment for chronic pain reported that their pain level was indeed lower after surgery (36). However, they also splayed less spontaneous activity. The anterior portion of the cingulated cortex has two main subdivisions (althoug ey are not clearly defined). The ventral portion tends to be more involved with emotional processing, while the orsal portion is more often associated with conscious thought. Activity in one of these sections inhibits activity in her (1). The net result is that strong emotional feelings interfere with conscious thought, while deep conscious ought quells emotions.

Finally, the anterior cingulated cortex is active during error recognition. Activity is increased in individuals ho realize they are making (or have made) a mistake. The activity is greatest in obsessive-compulsive individuals nd perfectionists (37). It is also high in empathetic people (1).

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Neuropsychology and Personality

The main function of the brain is to organize and integrate information gathered by sensory organs into a coherent representation of an organism's environment and to use this perception of the environment to generate appropriate behavior (9). In other words, the brain coordinates the information it gets via the five senses and generates a response. Since the brain governs the way an individual perceives the world as well as his or her actions, it is no surprise that personality can be greatly influenced by brain. The purpose of this website is to present information regarding the regions of the brain that affect (or potentially affect) an individual's personality. I've tried to organize the material sequentially and simply, so that this page can be useful to high school biology students.

The Basics

Before we move on to the more complicated and interesting stuff, there are some basic foundation facts that that are helpful to know about neurobiology and biology in general. With that in mind, here is a brief crash course in cellular biology.

First of all, all living organisms (except viruses) are composed of cells. A cell is the basic biological unit (like an atom in chemistry). A cell can be a small component of an organism, or an entire organism on its own. Its outer wall is something like a sea of fatty acids with various proteins floating around. Inside, there are more proteins catalyzing chemical reactions (these are called enzymes), genetic material (the chemical blueprint for an organism, which is called deoxyribonucleic acid, or DNA), and other molecules that the cell uses to maintain itself, such as sugars (for energy) and structural proteins.

There are two types of cells: prokaryotes and eukaryotes. Prokaryotes do not have a cell nucleus, which is the storage site for genetic material (DNA) in eukaryotes. Eukaryotes also have smaller structures within them called organelles. Organelles perform specific jobs within a cell that contribute to the cells survival, including energy production, protein manufacture and modification, breaking down contaminants, and storage of chemicals not currently in use.

Prokaryotes are always singe-celled organisms (like bacteria). All multi-celled organisms are composed of eukaryotic cells, including humans. Each cell in the human body has its own copy of that individual's DNA. However, even though every cell has the same blueprint, not all of the cells are the same. This is because not all of the cells read the same part of the DNA strand. Therefore, cells are able to differentiate depending on what job they need to do and work with other cells to help the organism survive.

There are many different cell types, but the two types most relevant to neuropsychology are neurons and glial cells. These are the two main cell types of the nervous system, of which the brain is a member.

Neurons are messenger cells. The send and receive signals via small electric pulses transmitted down long cellular processes called axons (send) and dendrites (receive). The place where the signal is handed from one neuron to the next is called a synapse. The synapse can either be chemical or electrical. Most synapses are chemical, which means that the signal is handed from the first neuron to the second by way of a chemical messenger, called a neurotransmitter. The neurotransmitter can either stimulate or inhibit another electrical pulse (another signal) in the next neuron. In an electrical synapse, the two neurons are in direct contact with one another and the electric pulse from the first continues right on into the next.

Neurons receive signals from sensory cells, such as pressure receptors in the skin (touch sense), and send them to higher processing centers where the information is analyzed and a response is generated. These higher processing centers include the brain and the spinal cord. Circuits of neurons then generate a response and still more neurons carry the response information to the appropriate destination (usually a muscle).

There are several types of glial cells, each with a different function. Some surround chemical synapses and modulate the amount of neurotransmitter that reaches the target cell. Some surround axons so that the signal travels faster. Still others play a maid role, and regulate the environment of the neurons.

The easiest way to think about all this is to compare your brain to a computer. There is some kind of input: a keystroke on your computer, or a signal from a taste receptor on your tongue for your brain. Then there is computation. Both systems use a bunch of 0's and 1's (off/on signals). The only difference is that a computer uses transistors, while your brain uses neurons. Then there is some kind of output. In your computer, the keystroke leads to a program opening. In your brain, the signal from your taste buds is processed and your brain sends the signal to chew and swallow the bite of pizza you just took.

Brain Anatomy

The human brain is composed of two roughly equal halves (hemispheres), each divided into the several parts. Among these are the medulla, the cerebellum, the pons, the midbrain, the hypothalamus, the thalamus, the basal ganglia, the limbic system, and the cerebral cortex (1). The table below highlights their functions.

Brain Division	**Major Function(s)**
Medulla	Controls heart rate and respiration
Cerebellum	Motor control
Pons	Information flow out of the brain
Midbrain	Processes auditory and visual input
Hypothalamus	Motivates self-preservation behavior
Thalamus	Data organization
Basal Ganglia	Motor control
Limbic System	Emotional integration and memory
Cerebral Cortex	Deciphers sensory input, object recognition, and conscious thought

no inflow?

The cerebral cortex is further divided into four lobes: the Frontal, Temporal, Parietal, and Occipital lobes. Each lobe performs several functions. The Frontal lobe contains the Olfactory Cortex, the Primary Motor Cortex, and is involved in executive function, working memory, and various emotional functions. (We'll return to the last three items shortly.) The Temporal lobe contains the Primary Auditory Cortex and the Occipital lobe contains the Primary Visual Cortex. The Parietal lobe contains the Primary Somatosensory Cortex, which is where sensory input is integrated into a coherent picture of the environment. The orientation of the four lobes is shown in the figure below.

There are many functions localized to specific parts of the cerebral cortex, so there are a few positional terms that you need to be familiar with. The 'dorsal' side of your brain ~~is the side~~ toward the top of your head. The 'ventral' side is the bottom of the brain, toward your neck. The 'anterior' is toward the front (your face), and the 'posterior' is near the bottom (toward the neck). 'Left' and 'right' refer to the two hemispheres of the brain, while 'lateral' and 'medial' denote a position away from and near to the middle, respectively (1). The notation is used as follows: the left dorsolateral frontal lobe indicates the portion of the frontal lobe that is hear the top and side of you head on the left side.

Phineas Gage and Injury Research

Phineas Gage was the first case of neuropsychological study, as well as the motivation for this website. In 1848, Gage was working as a railway foreman when an accident with an iron tamping rod caused severe damage to his brain (probably his frontal lobe). Gage was leveling rock at a railroad construction site in Vermont, when he dropped his tamping rod (3'8" long, 1.25" diameter) into a well of uncovered blasting powder. The powder exploding on contact and sent the iron rod rocketing through the bottom of Gage's jaw and out the top of his head (2). However, Gage did not die. Under the supervision of Dr. John Harlow, his wounds healed within a year, but his personality had completely changed. Before the accident, Gage was even-tempered, hard working, and competent. Afterwards, he was described as being very childish. Dr. Harlow, in his famous analysis of the case, observed that Gage had become short-tempered, impatient, easily distracted, rude, stubborn, and somewhat scatter-brained (2).

The case of Phineas Gage is characteristic of one of the major methods of neuropsychological research. That is, an interested investigator finds an individual with some sort of localized brain damage and studies any abnormal characteristics. If there is some sort of deficiency, the representative function is attributed to the damaged portion of the brain.

However, there are several obstacles in this method of research. First is that brain damage is almost never localized to one specific region of the brain (3). This can cause all sorts of problems with an experiment. First and foremost, it is difficult to tell which of the damaged regions accounts for the observed abnormal behavior. The only way to narrow it down is to perform multiple tests on multiple subjects with damage to overlapping areas. Even then it is very difficult to label a portion of the brain as having a specific function because there tend to be several areas of the brain that participate in one process. Furthermore, it is often difficult to gather a suitable group of test subjects. For instance, a thorough experiment would require a somewhat large group of subjects all with similar injuries, which is difficult to do, as survivors of selective brain damage tend to be in short supply (3). Despite all these roadblocks, there have been many successful studies on patients with brain damage, especially with damage to the prefrontal cortex (the region of the brain just behind the forehead).

Neuroimaging

Another major method of study is brain imaging, or neuroimaging. This type of research includes a whole range of noninvasive maneuvers, such as functional magnetic resonance imaging (fMRI), electroencephalogram (EEG), positron-emission tomography (PET), and computed tomography (CT). All of these procedures are different takes on the same concept: measure brain activity and/or health without surgery (3). These tests are performed on healthy and brain-damaged individuals in order to determine the activity (or inactivity) of various brain regions during specific activity. These experiments are highly valuable, because they have been able to accurately locate the processing centers for many important brain functions. such as?

Magnetic Resonance Imaging (MRI)

An MRI makes use of radio and magnetic waves to create a three dimensional image of soft tissue within the body. The test subject's entire body is placed inside small chamber made of a large magnet. The magnet causes all the hydrogen atom protons within the body to spin in the same direction, so that when a radio wave is applied, they emit a small signal of their own (4). A receiver collects these data and converts them into an image based on their calculated source. A functional MRI (fMRI) scan involves gathering several images of the brain in rapid succession and using the changes between these images to determine brain activity (7). Functional MRI scans are favored because they have a relatively high resolution both visually and temporally (1). That is, they show the brain in great detail, as well as being good at designating changes in activity over time.

Electroencephalogram (EEG)

An EEG uses electrodes attached to the scalp to measure electrical activity within the brain. Remember, the neurons in the brain fire off electric pulses when they are sending a signal, so measuring electrical activity really measures brain activity. This type of test is usually performed with some type of stimulus recognition experiment, because there are easily recognizable changes in electrical current within the brain when an individual identifies and analyzes a target object (5).

Positron-Emission Tomography (PET)

A PET scan utilizes a radioactive material injected into the test subject to measure the metabolism (or activity) of specific parts of the body (6). The procedure is fairly simple. The patient is injected with the radioactive material, which is associated with a specific molecule that the investigator wishes to follow, such as glucose (the body's main energy source), oxygen, or a neurotransmitter (1). The patient is then placed in a chamber much like an MRI chamber, except that there is a radiation sensitive material surrounding the subject rather than a magnet. When the body uses the radioactive material, gamma radiation is emitted and detected by the chamber walls. This information is used to generate a map of the body's usage of the targeted material (6).

Computed Tomography (CT)

Computed tomography, also referred to as Computed Axial Tomography (a CAT scan), is simply a cross sectional or three-dimensional composite of many x-ray images taken from many angles around the body. CT images can be used to find abnormal structures within the body, such as tumors and blood clots, or to study normal bone and organ tissue (8).

The general formula for experimentation with neuroimaging is to ask the test subject to perform some type of task or observe some stimulus that isolates the brain function the researcher wishes to study. While the test subject is performing the task, brain activity is measured by one of the above four tests. The experiment is usually repeated several times with each test subject using one or two different scanning methods. The experiment is also usually performed with a variety of different test subjects, both normal and brain-damaged.

more images in this + later sections would be helpful.

Prefrontal Cortex

The prefrontal cortex (PFC) is located in the frontal lobe, and has been shown to be active in executive function, working memory, and some emotional processing (9,10). The following overview of these functions serves the purpose of presenting the contribution of the PFC to the personality of an individual.

Executive Function

The simplest way to define executive function is the ability to plan an action (9). This process encompasses many steps. The first is to identify a goal or a need. Next, methods of achieving the goal are weighed as viable alternatives. When the best alternative is chosen, action is initiated. The tasks must often be performed in the proper order for the goal to be achieved. Motivation becomes an issue, as the goal may not be immediately achieved. There may be also be obstacles to progress, and problem-solving skills are employed to develop a new plan in order to continue on toward the ultimate goal. Finally, executive function terminates action (11).

Damage to the frontal lobe can negatively affect any number of these processes of executive function. However, due to the great number of connections the frontal lobe maintains within itself and with other parts of the brain, localization of these specific functions is difficult to demonstrate (1). The following is a brief summary of the various malfunctions of executive function.

Damage to the portions of the frontal lobe governing initiation of action causes a condition called psychological inertia (1). Individuals with damage to this portion of the brain have trouble with identifying needs and thus with beginning an activity. However, once they begin action, they have difficulty stopping. They are also easily influenced. For example, a researcher asked a patient with psychological inertia if he was thirsty. The patient responded that he was not. However, whenever the researcher suggested that the patient should take a drink if he was thirsty, the patient would always take a drink (1). This type of case is not limited to verbal cues, either. Individuals with psychological inertia will also respond to cues in their environment, a condition called environmental dependency syndrome (12). For example, if the subject sees a keyboard, he or she will sit down and begin typing.

Damage to the action initiation system seems to separate conscious thought from action (13). In tests where subjects were asked to sort cards into piles based a certain characteristics, they incorrectly sorted ~~the cards~~ while stating that they knew that they were doing so. This has led some researches to the opinion that psychological inertia, or a disconnection of thought and action within the frontal lobe, deprives these patients of their free will (1). Regardless of whether free will is involved in this problem, it is certain that a malfunction of action initiation has a severely detrimental effect on one's intellectual independence. Other types of damage to the medial PFC have been shown to decrease motivation in general (22). These results have implications regarding ambition and perfectionism (9).

A second malfunction of executive function can occur at the planning stage. At this stage in the process, the brain has set a goal and begins to use the information available to devise a plan (cognitive estimation) (1). When damage to the regions responsible for this function occurs, the individual is no longer capable of complex, or abstract, thought. These subjects are competent to follow concrete plans, but they are unable to create their own when given a goal (14). These individuals also tend to be deficient in estimation of mundane subjects, such as the price of appliances and groceries, or their own ability to plan and perform chores (15, 16). Finally, these patients have trouble estimating the potential behavior of other individuals (an ability called theory of mind), leading to a limited capacity for empathy (17). On a somewhat larger scale, these deficiencies mean that these patients do not have the capacity to plan out how to achieve something like a life goal or a New Year's Resolution, and they have difficulty working with a group to finish a task, because division of labor is a foreign concept to them.

Damage to executive regions may also cause deficiencies in problem solving skills (18). This is caused by mental inflexibility, or an inability to adopt an alternate point of view in dealing with the problem. This type of damage also affects the ability to adapt to new situations and to create new uses for an object (1). Habit rules the actions of individuals with this type of malfunction, because creativity is impossible.

Damage to the frontal lobe also has the potential to frustrate the ability to work toward a known goal (1). This includes focus, organization of steps (or sequencing), and progress analysis. The dorsolateral portion of the PFC has been implicated with the task of maintaining focus (1). This region keeps maintains an 'attentional set' of relevant information and actively works to exclude extraneous details (19). The ability to discern to proper of order of actions to take in order to best reach a goal can also be impaired by damage to the frontal lobe. This type of deficiency might cause an individual to mail out a blank set of college application forms before filling out another set, which might be left at home. Finally, dysfunction in the frontal lobes can result in an inability to judge whether a task is actually helping to achieve a goal (1). The combination of these three deficiencies results in erratic behavior, similar to ADHD and the behavior of Phineas Gage after his accident.

Two prominent theories concerning the mechanism of executive function are the supervisory attention system (SAS) theory and the executive knowledge model (9). The SAS theory views executive function as being similar to a computer program in the way it deals with a problem. It states that there are 'schemas,' or pre-programmed, automated plans, on how to deal with the mundane situations that an individual might encounter (20). For example, the electric bill-paying schema would involve finding the checkbook, writing a check for the amount of the bill, and mailing the bill to the electric company. Learned triggers (receipt of the bill in the above example) prompt the brain to action in these scenarios. The supervisory attentional system (SAS) comes into play when a novel situation is encountered or a behavioral change is attempted (i.e. trying to break a habit). The SAS is responsible for analyzing the problem, developing a plan, initiating action, and monitoring progress (20). The SAS also oversees the appointment of schemas to ensure that the correct one is chosen for a given task (left dorsolateral PFC), searches the memory for the appropriate actions (right ventrolateral PFC), and monitors behavior (right dorsolateral PFC).

This theory is particularly strong because it includes a model for the interaction between the nature and nurture aspects of an individual, because the events that trigger an action schema are learned, not programmed. In other words, the SAS theory helps to reconcile the two major perspectives on how a personality is forged. Another way to explain this concept is the transactional model of behavior. The transactional model states that an individual's natural qualities and his or her environment each has an effect on the other (3). That is, an individual can affect his or her environment, which in return affects the individual, who learns and responds to the environment, and so on. The learning of schema triggers is also a good way to imagine how habits are formed.

Another model that incorporates the influence of the environment into behavior patterns is the executive knowledge model (9). This model states that managerial knowledge units (MKUs) are stored in the PFC. These MKUs are similar to the schemas in the SAS model. They are arranged in a hierarchy (ladder system) of simple to complex behaviors. Simple MKUs become associated with another by learning and experience to generate responses to more complex situations (1). The more often an MKU is called into use, the more automatic and ingrained that behavior becomes. Thus, we have another mechanism for habit, as well as an explanation for the maintenance of mundane capabilities even in individuals with damage to the frontal lobe.

The effects of executive function on the personality of an individual can most easily be demonstrated by reviewing the case of Phineas Gage. Recall that after his accident, Gage was easily distracted, scatterbrained, and somewhat irresponsible. These are all symptoms of damage to the frontal lobe and executive function. Differences in these traits can also exist in normal individuals. While most people have the DNA necessary to build a brain, no two people have the exact same DNA. That means that there will be minor differences between the brains of any two people. These differences will be analogous to the difference in height, weight, and hair color those two people might have. These differences in the blueprints that each brain is built with can cause minor differences in the some of the processes. Thus, one individual may be slightly better at dealing with new situations than another. Life experience can also cause differences between brains. Since learning is heavily involved in the development of schemas or MKUs - depending on which theory you prefer - experience is incorporated into the physical aspects of the brain (as memory). These experiences then resurface as behavior.

Working Memory

Working memory, localized mainly in the dorsolateral PFC, is basically the attentional set of executive function. It holds a small amount of information relevant to the task at hand for a few seconds (1). Recent studies have shown that it also plays a role in anticipating events (21). This is a logical function, because as a holding point for knowledge of past events, it is ideally placed to relate possible future events based on observed patterns.

Deficits in working memory have a drastic effect on an individual's ability to interpret events. Since less information is in storage about current events, it is more difficult to build relationships to the preceding events. The result is that pattern recognition and planning ability are negatively impacted, and the individual becomes dependent on more recent stimuli to determine action (1).

Emotional Control

It has been frequently demonstrated that the ventral prefrontal cortex is intimately tied to the limbic system, which is one of the primary systems responsible for emotional processing (9).

The ventral PFC controls positive conditioning (reward associations), as well as inhibition; damage to the lateral ventral PFC has caused irritability and impulsive decision making (23). The same study also showed that ventromedial PFC plays a role in risk assessment. Subjects with damage to the medial ventral PFC continually gambled on high risk bets that had a greater immediate value, but had less value in the long run. Other research indicates that the ventromedial PFC responds rapidly to emotional stumuli and probably plays a first response role (25).

Several other studies have demonstrated a connection between the orbitofrontal PFC (the region along the front bottom edge of the brain) and positive sensations from the taste, sight, and smell senses (1). Some of these experiments have also found that people with damage to the OFC disconnect their consequences from their actions and frequently behave inappropriately (24). These subjects tend to disregard the possible results of their actions in their attempts to obtain the most immediate gratification. One study even linked the OFC to moral values (24). The OFC also seems to be functional during the re-learning process. For example, in a test where the rules changed, subjects with damage to the OFC were unable to adapt (1).

It is reasonable to conclude that the dorsolateral PFC (DLPFC), with its role in working memory and focus, also has some role in emotional processes, since most people have experienced how emotion can affect the thought patterns (1). As stated above, the DLPFC is charged with the responsibility of integrating past experiences into current activity. When emotional control is added to this responsibility this region becomes extremely important for ~~self-perception~~ (9). The role of the DLPFC in executive function and emotional integration leads action based on emotion in a positive response (approach) or negative response (withdrawal) pattern (26). The two response classes are localized to the two hemispheres: the approach to the left and withdrawal to the right.

The DLPFC isn't the only region of the PFC that displays a different function in each hemisphere. In fact, the whole PFC seems to be divided. Damage to the left PFC causes a 'catastrophic reaction' where subjects experience something like a continuous emotional breakdown (the right side regulates negative feelings). On the right side, damage causes a 'euphoric indifference' reaction, where subjects are in a perpetually good mood despite their injuries (the left side regulates positive feelings) (27). The two halves seem to contend with one another to form a balance of mood. The balance of activity can fall on different points of a mood continuum depending on the individual. In other words, this type of brain activity is a factor in whether an individual has an overall positive or negative attitude.

The Parietal Lobe

Two of the major functions of the Parietal Lobe are integration and interpretation. The parietal lobe is the site where information from sensory input converges and is molded into a representation of the surrounding environment. The parietal lobe is also the region where emotional stimuli are interpreted (1).

One of the primary functions of the right parietal lobe, as far as emotional processing is concerned, is to interpret visual and auditory emotional content, such as facial expressions and tone of voice (1). The right parietal lobe is where the brain makes the jump from observing a frown and slanted eyebrows to noticing that the person it is seeing is angry (28). This social skill is enormously important, as a great deal of communication is accomplished with body language. Interpreting tone of voice, or prosody, and more importantly, integrating tone of voice with facial expressions is another task of the right parietal lobe.

Patients with damage to the right hemisphere have serious problems assessing their social surroundings, but also have difficulty with assessing the rest of their environment. The parietal lobe's function in integrating other sensory input it the main cause of this deficiency. Research on story interpretation has suggested that skepticism is another function of right parietal lobe, as subjects with damaged right hemispheres displayed poor comprehension and judgment of plot (29).

The right parietal lobe is also responsible for emotional display. Prosody and facial expressions are both controlled by the right side (1). It is interesting to note, however, that the right side is not solely responsible for emotional output. The left side moderates the emotional output of the right side. This relationship roughly corresponds to a conscious control of subconscious emotion (30). This phenomenon is actually visible in many facial expressions. The left side of the face - controlled by the right hemisphere - tends to display more emotional content than the right side of the face, which is controlled by the left hemisphere (30).

The affects of the parietal lobe on personality are potentially very great. Since personality depends on perception of the individual's environment, it is also dependent on the ability of the parietal lobe to interpret and integrate sensory input. Dominance changes between right and left hemispheres can also lead to an individual showing more or less emotion, respectively.

The Amygdala

The amygdala is a part of the limbic system, which was the recognized center for emotional processing. Other structures of the limbic system include the hypothalamus, the ~~thalamus~~, the hippocampus, and the cingulate cortex.

fornix
septal nucleus
mammillary bodies

The amygdala has strong connections to negative feelings such as fear and suspicion (1). It is responsible for helping to identify alarming sounds, and also responds when an individual sees or hears something that he or she is afraid of (31,1). Two of the most important functions of the amygdala seem to be fear conditioning and emotional memory (32, 33). Fear conditioning is the subconscious association of neutral stimulus with a negative one. A simple example is dog training. In order to train a dog not to jump on the couch, its owner shakes a can of coins at it every time the dog jumps up. Eventually, the dog begins to associate jumping up on the couch with the unpleasant noise, and ceases its attempts to lie on the couch.

Fear conditioning depends on a link between the memory of the negative stimulus and the fear response it generates. This is another function of the amygdala. Fear responses are in many cases a necessary element of the self-preservation instinct, so events causing fear must be faithfully recorded. The special attention given by the amygdala and other structures to remembering threatening situations is called the memory enhancement effect (33).

Fear responses often require quick action as well as clear thought. In order to accomplish both of these, there are two main routes that information can take to reach the amygdala (1). One route is directly into the amygdala from the thalamus (the brain's incoming information distribution center). This route allows the amygdala to perform a rough assessment of the situation and generate action quickly (34). The second route carries the signal through the neocortex, first, so that a more complete appraisal of the situation is possible.

Much of the work performed by the amygdala is subconscious, and this has sparked some interesting research. One line of study, called race evaluation, measures the unconscious attitudes of people toward other races. Amygdala activity (fear response) is measured by fMRI while test subjects are shown faces or individuals belonging to different ethnic groups. This research has shown that consciously stated opinion and subconscious response do not necessarily agree with one another (35). This leads to some rather interesting ideas. Fear may be permanently hardwired into the brain; it may be impossible to overcome. Biases obtained in early developmental stages may be irreversible, as well.

The Hippocampus

The hippocampus is largely responsible for organizing and storing long-term memory (1). This information also includes emotional content; the hippocampus is the site where emotion is applied to specific situations and types of situations in memory. For example, running away from another competitor in a race is associated with a much different emotional sensation that running away from an angry bully. The ability to store this type of information in effect gives the hippocampus 'authority' over emotional context and appropriate emotional expression (26).

The Cingulate Cortex

The cingulated cortex, which wraps around the top middle part of the brain, has a variety of functions. One of them is general pain perception. Subjects who received surgical damage to their anterior cingulated cortex as a treatment for chronic pain reported that their pain level was indeed lower after surgery (36). However, they also displayed less spontaneous activity. The anterior portion of the cingulated cortex has two main subdivisions (although they are not clearly defined). The ventral portion tends to be more involved with emotional processing, while the dorsal portion is more often associated with conscious thought. Activity in one of these sections inhibits activity in other (1). The net result is that strong emotional feelings interfere with conscious thought, while deep conscious thought quells emotions.

Finally, the anterior cingulated cortex is active during error recognition. Activity is increased in individuals who realize they are making (or have made) a mistake. The activity is greatest in obsessive-compulsive individuals and perfectionists (37). It is also high in empathetic people (1).

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